



A Rapidly Prototyped Vegetation Dryness Index Evaluated for Wildfire Risk Assessment at Stennis Space Center

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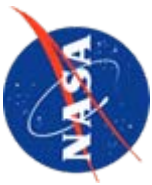
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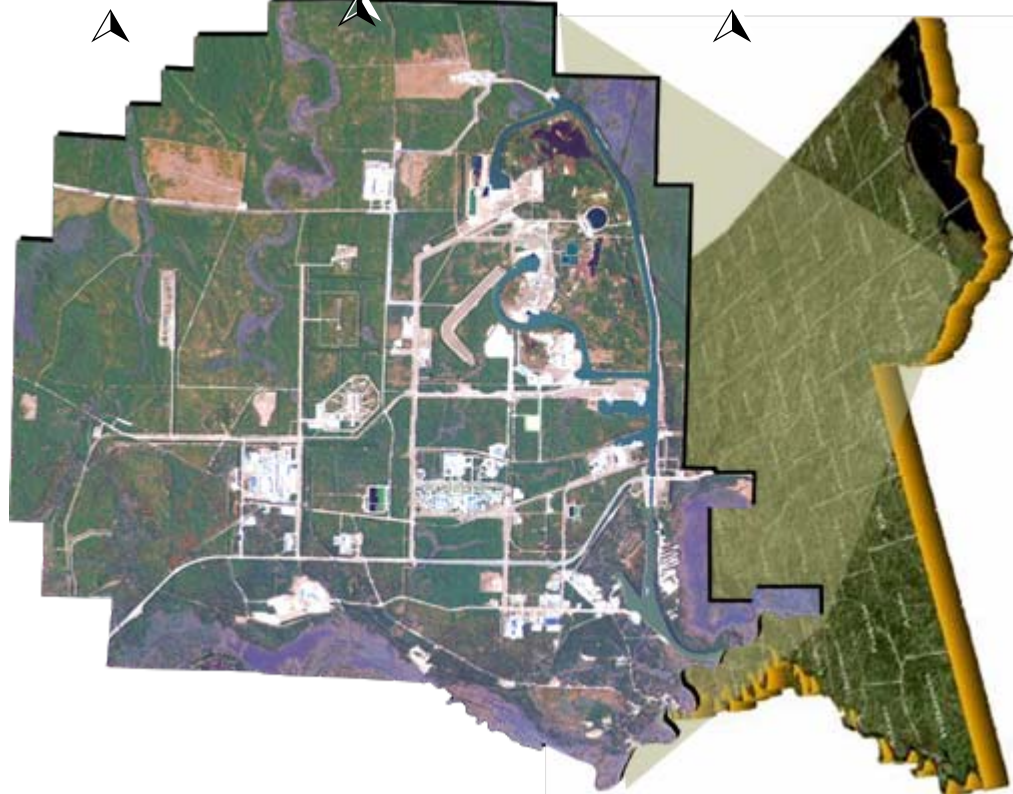
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May 11, 2007



Background

Stennis Space Center The Federal and Commercial City

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➤ Land

➤ **138,871 Acres**

- Fee Area (Fee Simple)
- Buffer Zone

– 13,800 Acres

– 125,071 Acres

➤ Buildings/Facilities

– Structures

– 142

– Building space

– 1.5 Million sq ft

– Canals

– 8 Miles

– Roads

– 45 Miles

➤ Population

– Personnel

– 4600

– Scientists & Engineers

– 1700

– Federal & State Agencies

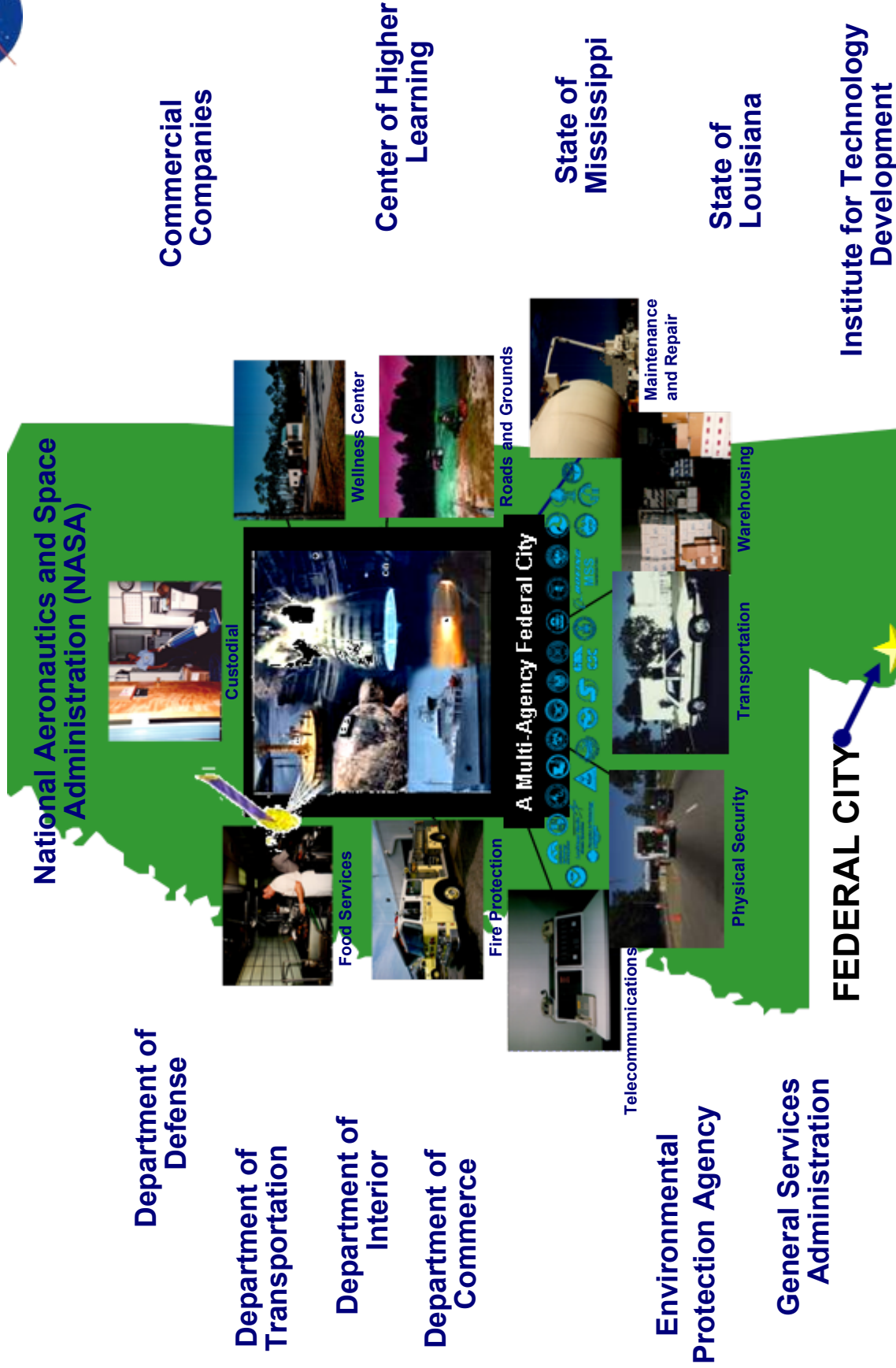
– Over 30

– Technology Companies

– Over 60

The Federal and Commercial City

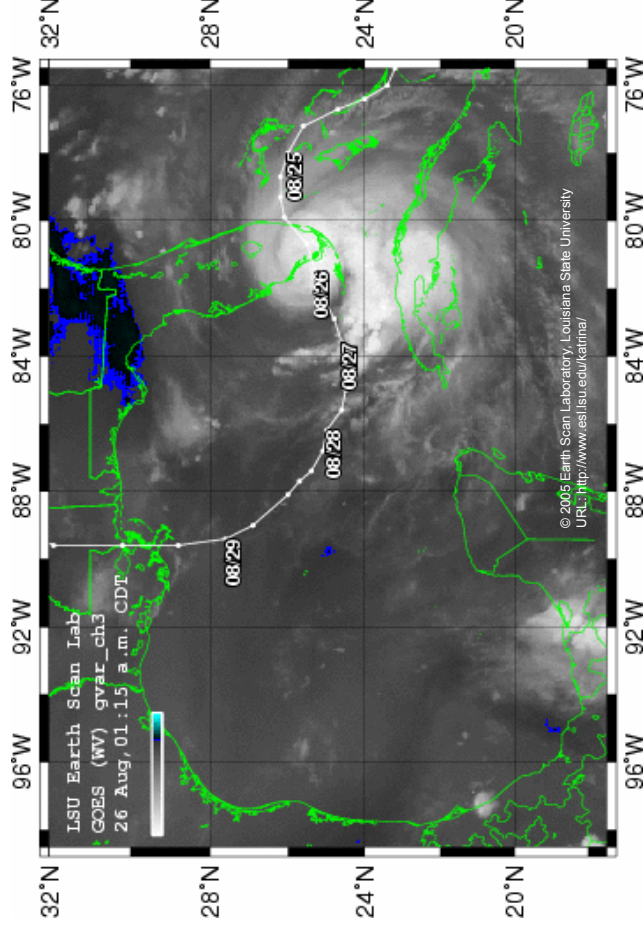
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Problem 1: Hurricane Katrina



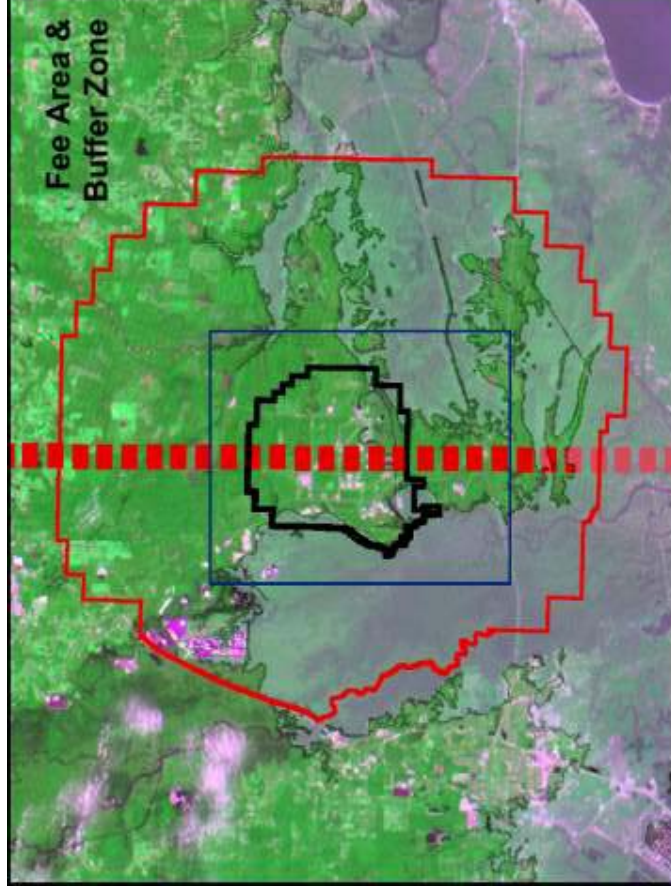
- Hurricane Katrina made its third and final landfall on the morning of August 29, 2005, near the LA/MS border about 10 miles from the center of Stennis Space Center (SSC)
- It was defined as a Category 3 storm with sustained winds of 125 mph
- Maximum storm surge (24 to 28 feet) came ashore about 15 miles south-southwest of SSC centered on St. Louis Bay



Immediate Storm Impacts on SSC



- SSC was closed for normal operations for about one month because of storm damage
- 152 building suffered some type of damage with 62 suffering moderate to severe damage
- 3,700 people (including employees, their families and the public) sought shelter at SSC



Surge surrounded Stennis Space Center on 3 sides

- *Main East-West surface transportation corridors cut off*
- *However, center infrastructure largely not affected (validating original choice of site)*

Storm Impacts on Forests

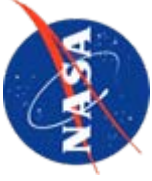


De Soto National Forest

Centered 45 miles northeast of SSC, with estimated wind intensity slightly lower, the U.S. Forest Service found that about 70% of trees sampled had some level of damage, with over 40% displaying severe damage that would likely result in the death of the tree (Meeker et al., 2006).



- *Forest damage at SSC probably more severe*
- *NLCD 2001 estimated forests to cover over 75% of SSC*
- *Large, sudden shift from live vegetation to dead materials surrounding SSC infrastructure*



Supporting Center Response & Recovery

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SSC/ARTPO implemented a systems engineering approach to

- Characterize the properties of geospatial information relevant to SSC concerns
- Add value to geospatial data sources so they met SSC information requirements
- Create information products to meet specific SSC recovery needs

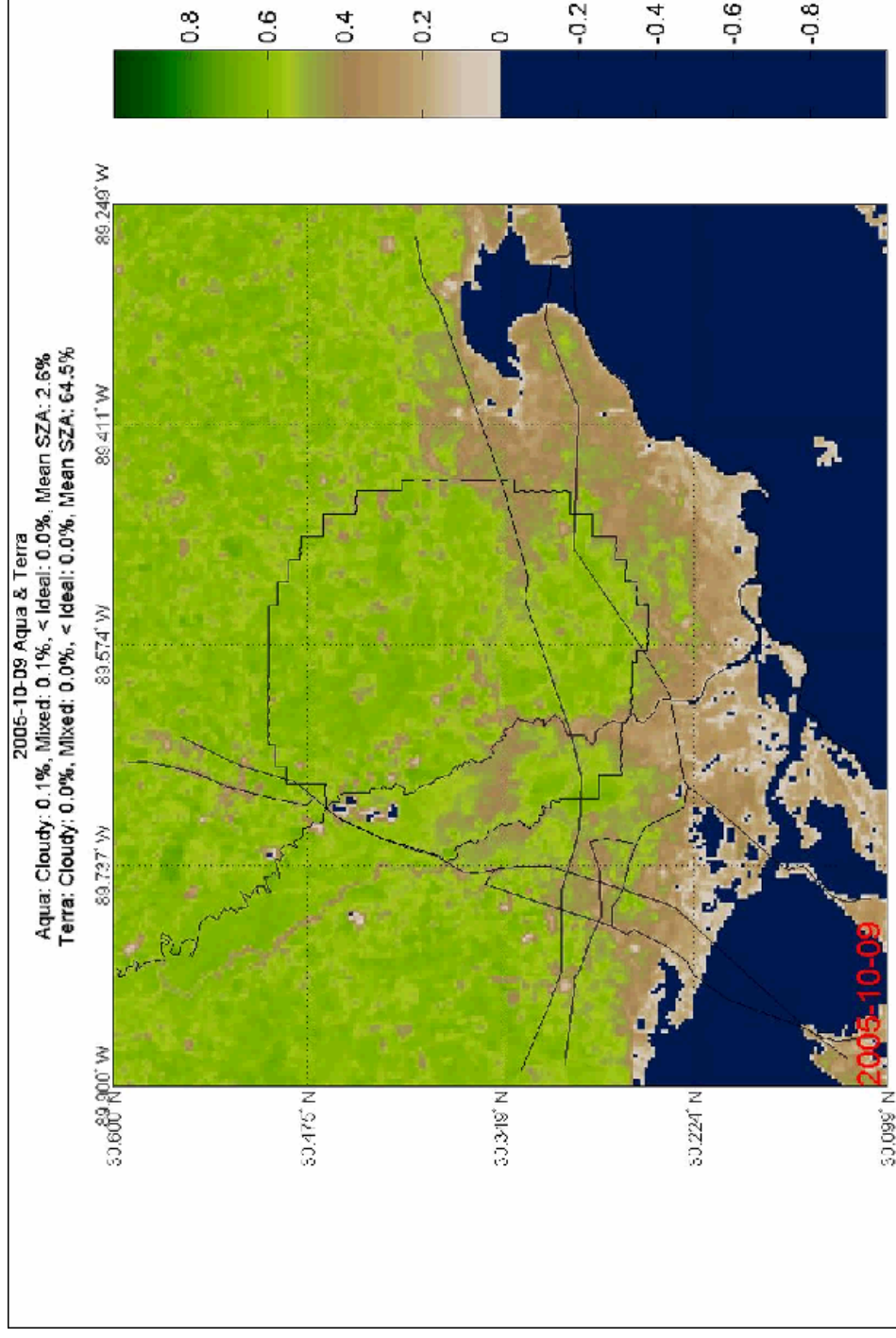
Systems Engineering Efforts



- Characterized FEMA high water mark/surge inundation level estimates
- Characterized remote sensing products ranging from 30cm airborne to 56m satellite
- Converted multispectral sources (ALI, ASTER, AWiFS, IKONOS, QuickBird, Landsat 5) to planetary reflectance to allow comparison and change detection
- Orthorectified high-resolution satellite imagery for a base map for the center “Fee Area” as well as the surrounding acoustic buffer zone
- Created all-source integrated products to highlight surge/flooding risk posture
- **Created both map and multitemporal vegetation change products**

Temporal Analysis of SSC Area Vegetation Impacts with NASA MODIS Data

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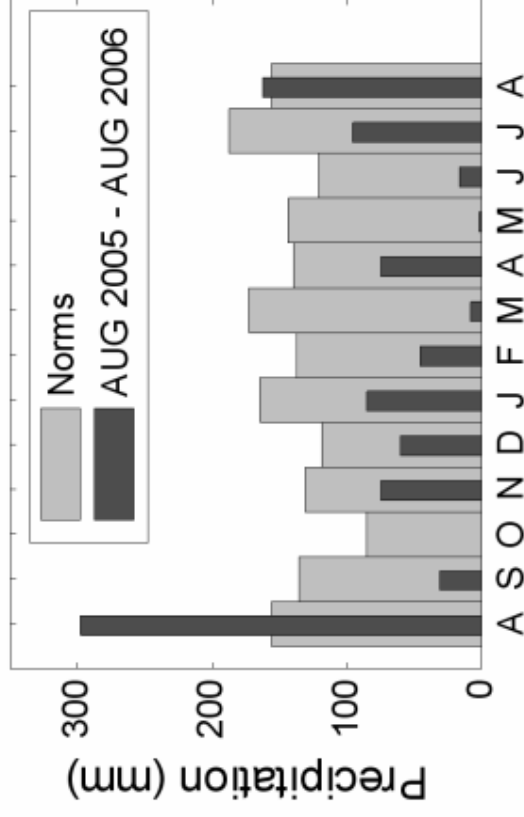
Katrina New.avi

Problem 2: 2005-2006 Drought



- After Hurricane Katrina cleared the Gulf Coast, there was little rainfall until November. At the same time, injured trees responded with a “second spring” rapidly sprouting new growth. The combined effects may have exacerbated forest losses.
- Winter rains were about half normal leading to critically low available soil water in spring.
- There was almost no precipitation in March, May, and June with only a brief respite in April.

SSC 2005-2006 Rainfall



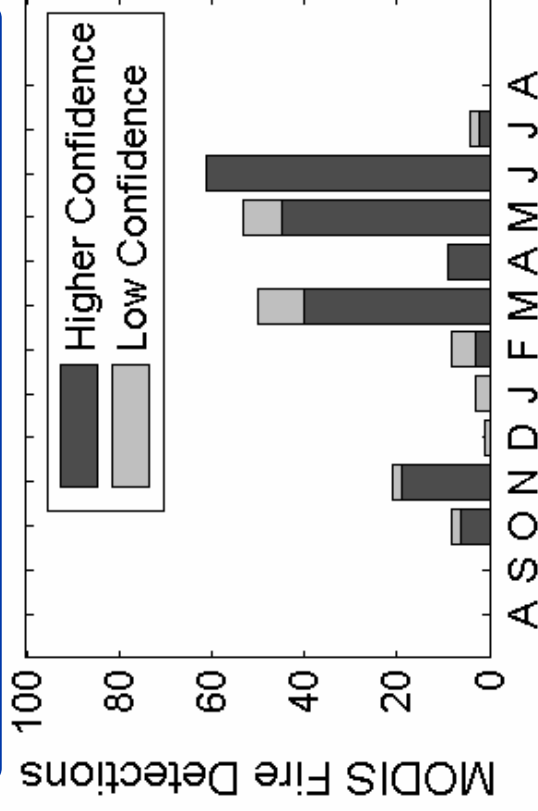
Drought/Fire Relationship in Forests Near SSC

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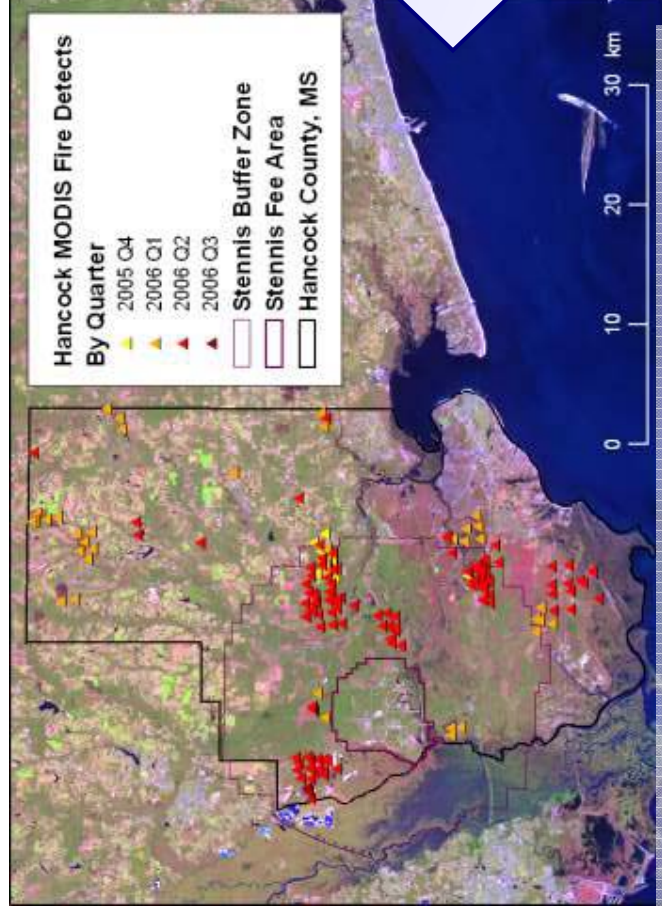


Spikes in detection of fires in Hancock County, MS (which include the SSC Fee Area) closely matched months with critically low rainfall.

Hancock Co. 2005-2006 Fires



The buffer zone around SSC, with less fragmented upland forests had a greater concentration of fires than the rest of Hancock County.



Applying Vegetation Change to Drought & Fire Risk

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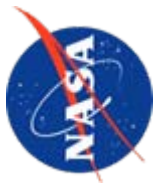


Extended vegetation change detection approach to capture both vulnerability and damage

- Observed seasonal change at medium resolution
- Observed short term change at lower resolution/higher temporal frequency to capture sudden disturbances



- *High temporal frequency MODIS data better at distinguishing fire from phenology or stress*
- *Moderate (Landsat-like) resolutions better at delineating burned areas*



Rapid Prototyping of a Vegetation Dryness Index

Requirement Defined



- As drought and fire risk around SSC became more acute, it became apparent that monitoring vegetation change alone was an incomplete solution
 - Vegetation change was essentially capturing a post mortem view of the danger
 - Vegetation change monitoring identified regional danger, but did not provide a spatial focus on areas of highest risk
- To better manage resources and protect infrastructure, decision makers would be ideally served with an information product that highlighted spatial variations in vegetation moisture as an estimate of risk prior to ignition



Potential Solutions Identified from Literature

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- Identified several classes of remote sensing products used in monitoring vegetation moisture stress, drought and wildfire danger:
 - Tasseled-cap wetness (e.g., Healey et al., 2005)
 - Relative greenness (e.g., Bartlette & Borgan, 1994)
 - NDVI to thermal ratio (e.g., Chuvieco et al., 2003)
 - Indices of NIR ($\sim 0.8 \mu\text{m}$) and SWIR ($\sim 1.6 \mu\text{m}$)
 - Many of these were of the “normalized difference” with the general form $(\text{NIR} - \text{SWIR})/(\text{NIR} + \text{SWIR})$. This was variously termed NDMI (Normalized Difference Moisture Index), NDWI (Normalized Difference Water Index), and even others (e.g., Dennison et al., 2005).
 - An interesting variant, VDI (Vegetation Dryness Index), combined NDMI and NDVI to map out a dryness indicator with reduced influence of phenology (Maki et al., 2004).

Selecting an Approach



- The approach was largely determined by available data
 - Variety of multispectral sources made tasseled cap difficult
 - Long download time and processing requirements to establish multi-year norms made relative greenness difficult
 - Many available data sources did not have a thermal capability, which left the methods combining NIR and SWIR
- Preliminary analysis of NDMI over SSC showed strong land cover and phenology dependencies
- Based on this process of elimination, attention was focused on the VDI

Notes on Estimating VDI

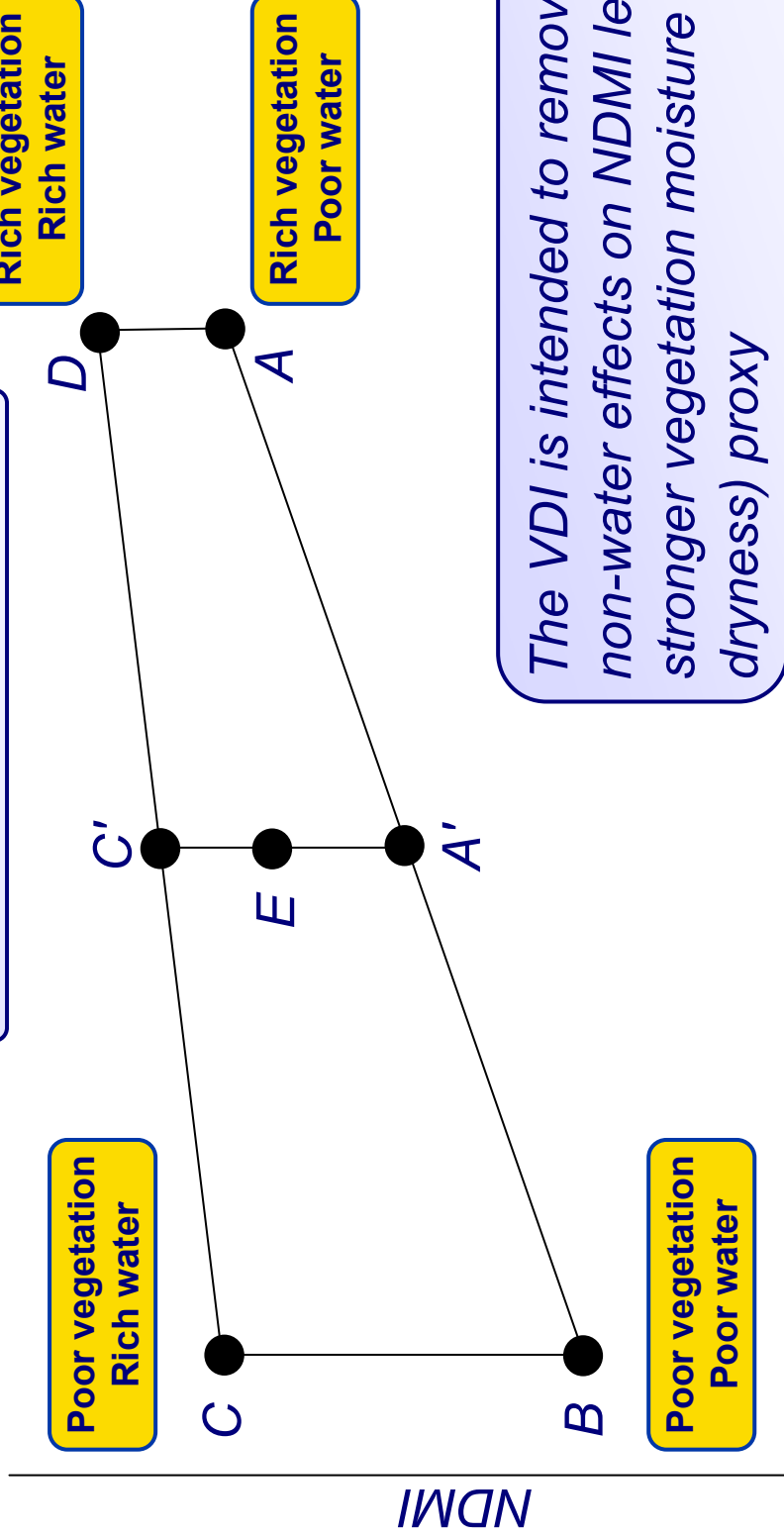


- NDVI and NDMI are estimated over a representative time period and area of interest to define a two-dimensional feature space
- A trapezoid is used to bound the data distribution within the feature space
 - For NDVI, the upper side of the trapezoid is $NDVI = 1$ and the lower side is $NDVI = 0.3$. No points with NDVI below 0.3 are included with the notion that lower biomass poses minimal wildfire risk.
 - The remaining 2 sides of the trapezoid are best fit to the wetter and dryer bounds of the NDMI-NDVI data distribution



Calculating VDI

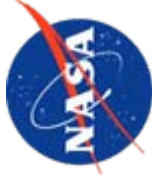
$$VDI \text{ for } E = 1 - (A'E/A'C)$$



NDVI

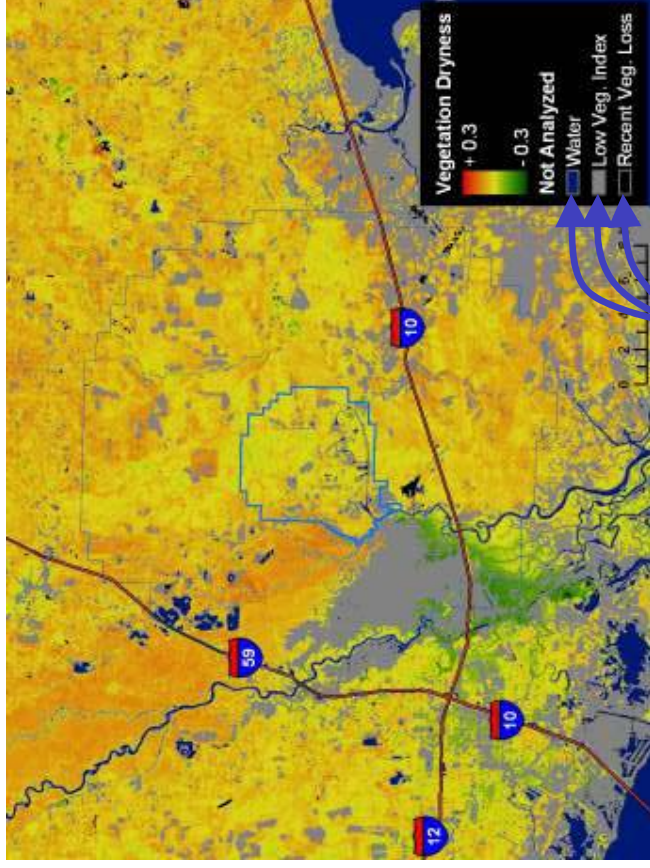
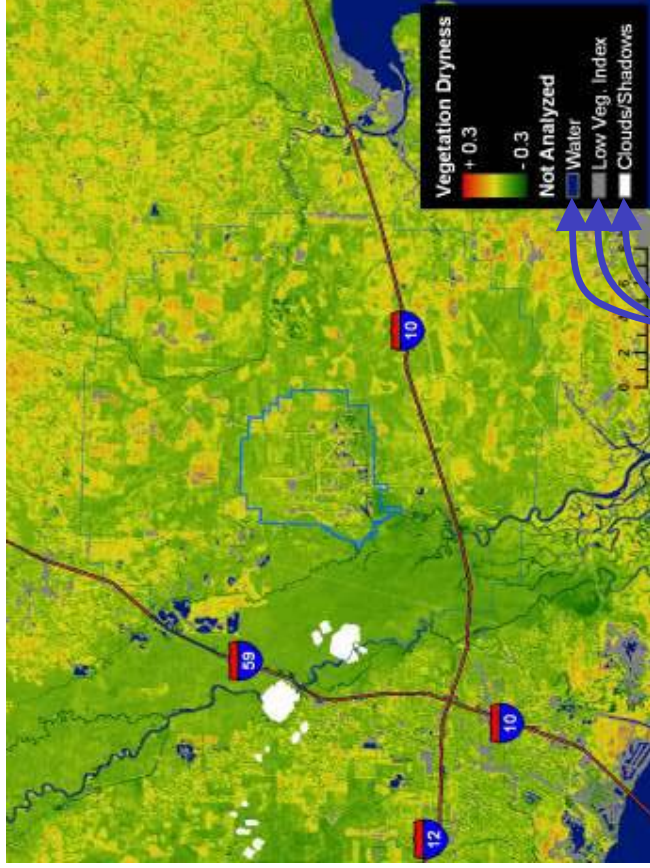
Figure adapted from Maki et al., 2004

Initial Prototyping



Landsat 5, 27 Apr 05 (wet)

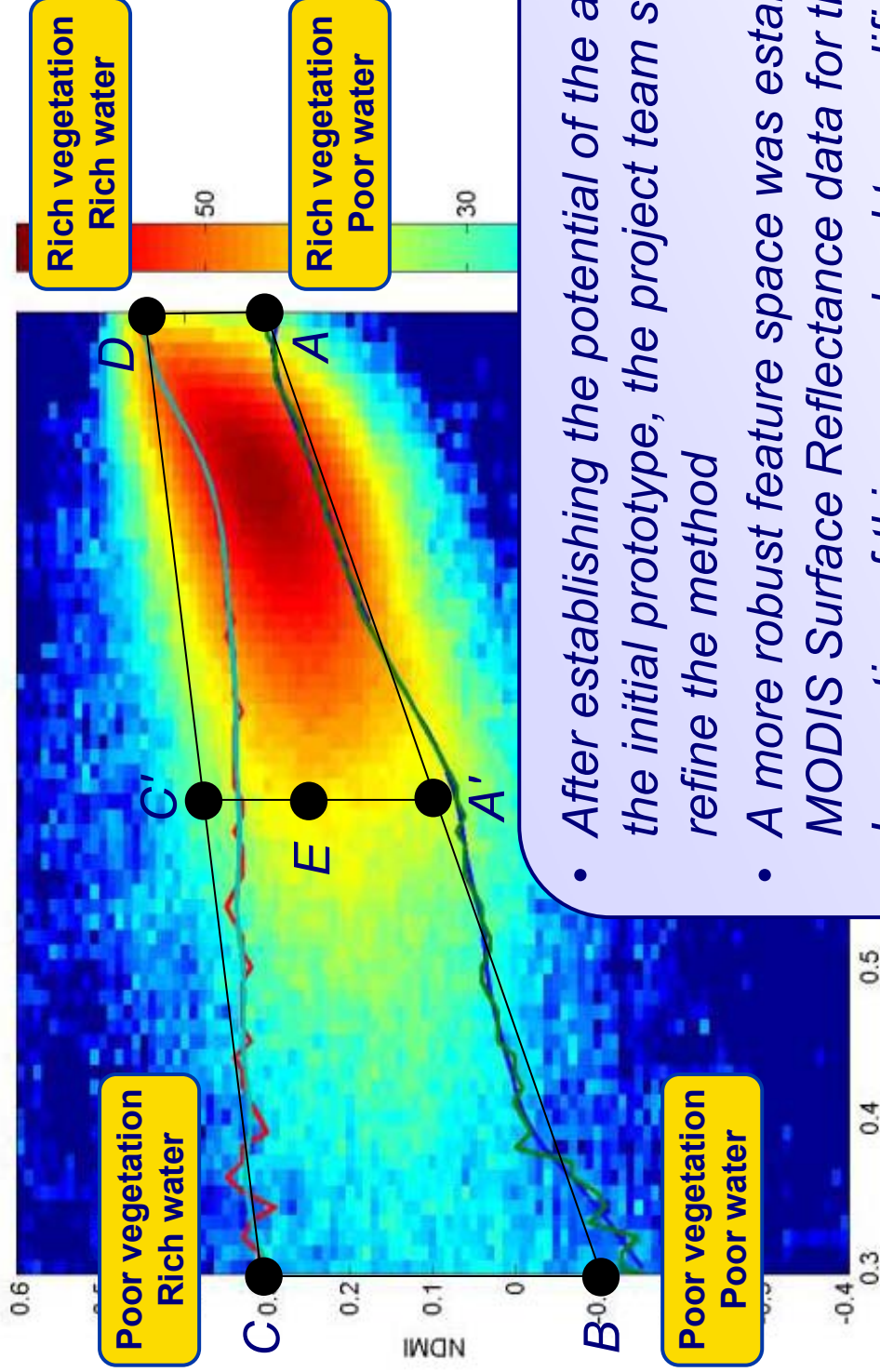
AWiFS, 15 Mar 06 (dry)



Certain cover categories are masked. These categories tend not yield reasonable estimates, and they are also less relevant to assessing fire risk.

Updating the Prototype

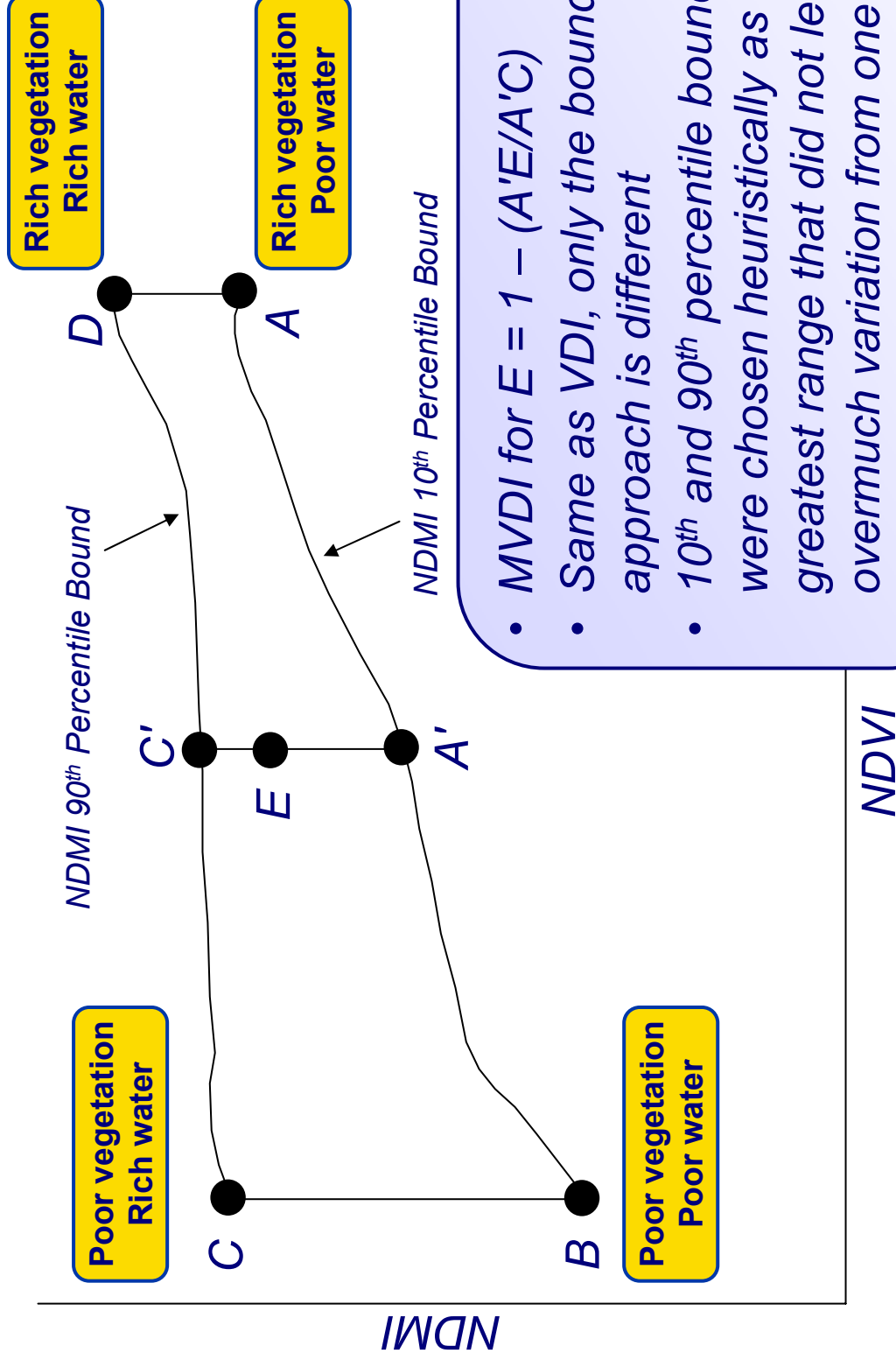
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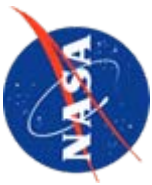
- After establishing the potential of the approach with the initial prototype, the project team sought to refine the method
- A more robust feature space was established using MODIS Surface Reflectance data for the year 2005
- Inspection of this space lead to modification of the wetter and drier bounds to a percentile approach instead of a simple linear bound

Calculating Modified Vegetation Dryness Index (MVDI)

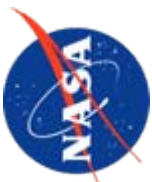
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- $MVDI \text{ for } E = 1 - (A'E/A'C)$
- Same as VDI, only the bounding approach is different
- 10th and 90th percentile bounds were chosen heuristically as the greatest range that did not lead to overmuch variation from one NDVI bin to the next



Results



MVDI – NDMI – NDVI (1)

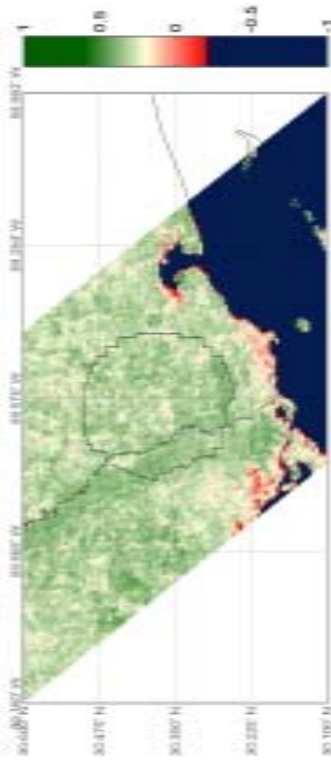
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10 Sep 05

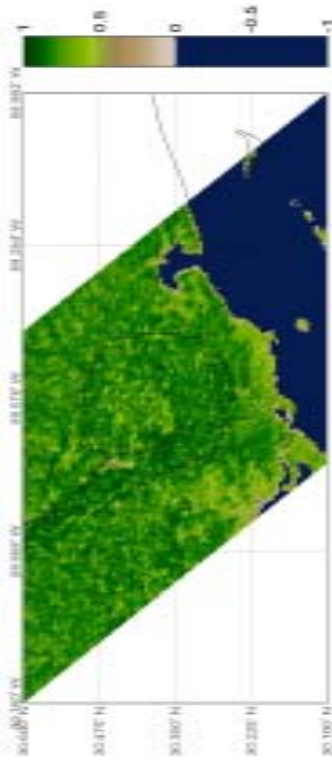
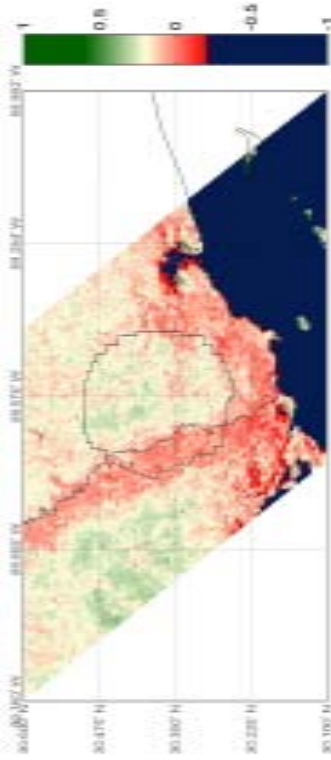
15 Jul 05



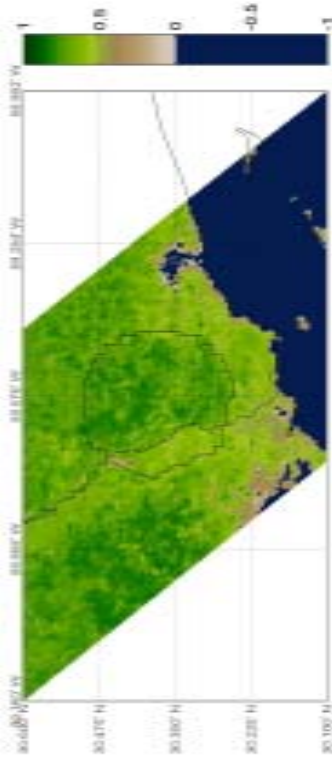
MVDI

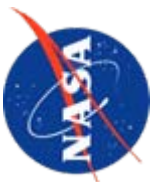


NDMI



NDVI



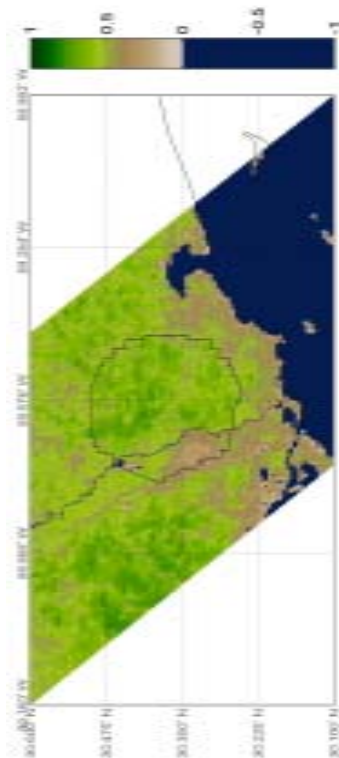
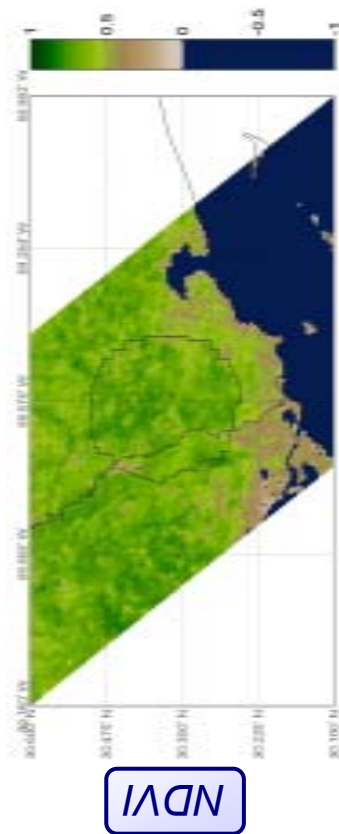
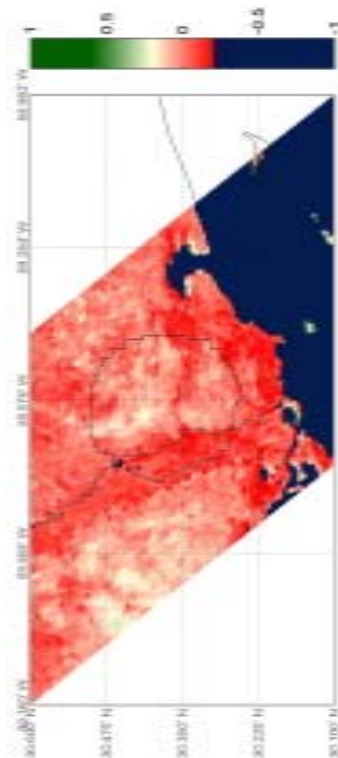
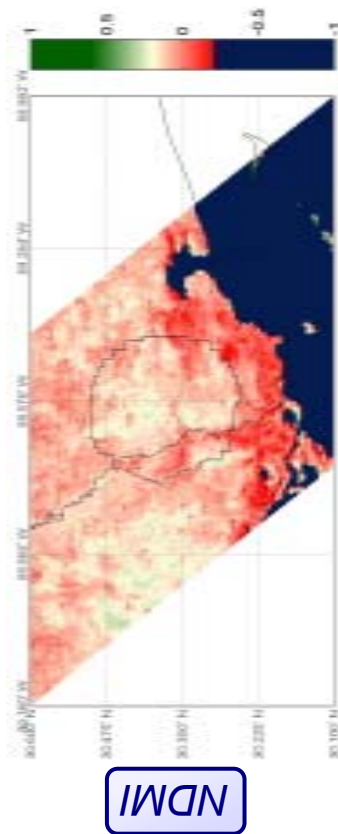


MVDI – NDMI – NDVI (2)

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5 Feb 06

15 Nov 05



Cross-Product Comparison Summary

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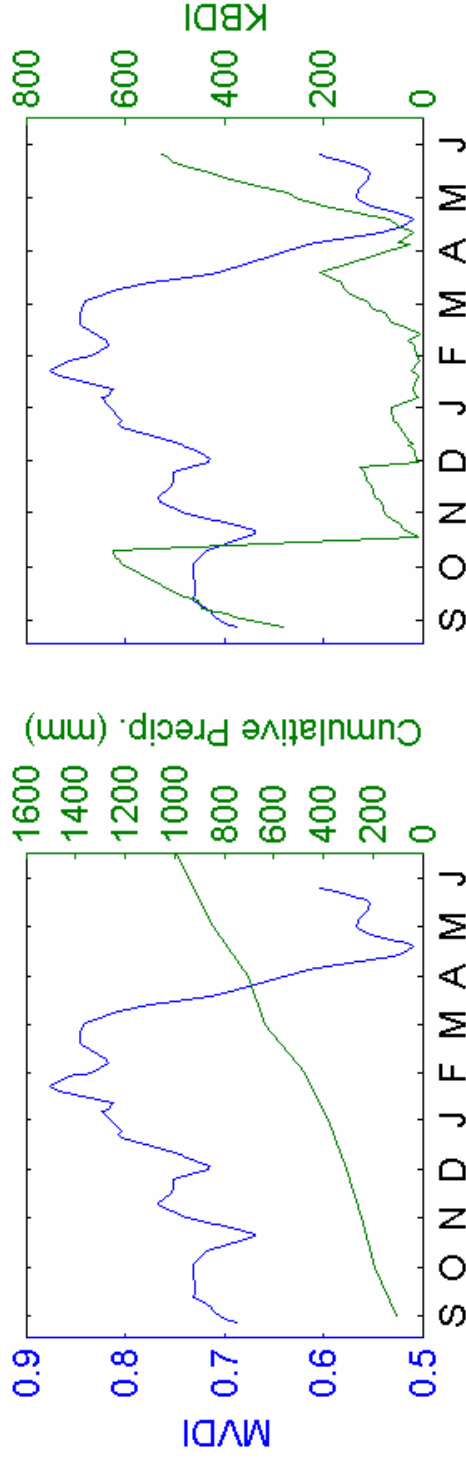


- The MVDI products all appear to be “noisy.”
- Wetlands tend to appear drier than uplands.
- For the period evaluated, as the drought deepened all indices were consistent with worsening conditions. This did not allow a direct comparison of a situation where overall vegetation condition and vegetation moisture were moving in different directions.



MVDI Relationship with Fire Weather

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- Comparing MVDI averaged across the SSC acoustic buffer zone with products based on local weather and fire weather stations, a complex relationship is revealed
- The overall trend fits well with the cumulative precipitation deficit, but it reverses its relationship during spring green-up
- MVDI tends to show drops in concord with the Keetch-Byram Drought Index (KBDI) – both in response to rainfall events, but again the MVDI is affected by spring green-up where the KBDI is not



Conclusions

- MVDI, which effectively involves the differencing of NDMI and NDVI, appears to display increased noise that is consistent with a differencing technique.
- This effect masks finer variations in vegetation moisture, preventing MVDI from fulfilling the requirement of giving decision makers insight into spatial variation of fire risk.
- MVDI shows dependencies on land cover and phenology which also argue against its use as a fire risk proxy in an area of diverse and fragmented land covers.
- The conclusion of the rapid prototyping effort is that MVDI should not be implemented for SSC decision support.



Next Steps

- Recommendation 1: Any remote sensing product assessing fire danger at SSC must take land cover into account. Land cover should probably be updated annually for normal conditions and seasonally in dynamic conditions such as those that followed Hurricane Katrina.
- Recommendation 2: Remote sensing based estimates should be coupled with fire weather station network information such as the USDA's Weather Information Management System (WIMS).
- Recommendation 3: Any further work with MVDI or similar combination index should apply noise reduction approaches such as temporal or spatial averaging.



References

- Bartlette, R.A., and R.E. Burgan, 1994. Vegetation condition and fire occurrence: a remote sensing connection. *Proceedings of the 1994 Interior West Fire Council Meeting and Program*, November 1-4, 1994, Coeur d'Alene, ID, pp. 273-279, [http://www.firelab.org/old/fbp/fbpubs/fbpubs/rbartlette/vegcondition.pdf](http://www.firelab.org/old/fbp/fbpubs/fbpubs/fbpubs/rbartlette/vegcondition.pdf), accessed April 18, 2007.
- Chuvieco, E., I. Aguado, D. Cocero, and D. Riaño, 2003. Design of an empirical index to estimate fuel moisture content from NOAA-AVHRR images in forest danger studies. *International Journal of Remote Sensing* 24(8):1621-1637.
- Dennison, P.E., D.A. Roberts, S.H. Peterson, and J. Rechel, 2005. Use of normalized difference water index for monitoring live fuel moisture. *International Journal of Remote Sensing* 26(5):1035-1042.
- Healey, S.P., W.B. Cohen, Y. Zhiqiang, and O.N. Krankina, 2005. Comparison of tasseled cap-based Landsat data structures for use in forest disturbance detection. *Remote Sensing of Environment* 97: 301-310.
- Maki, M., M. Ishiahra, and M. Tamura, 2004. Estimation of leaf status to monitor the risk of forest fires using remotely sensed data. *Remote Sensing of Environment* 90: 441-450.
- Meeker, J.R., T.J. Haley, S.D. Petty, and J.W. Windham, 2006. Forest health evaluation of Hurricane Katrina tree damage: De Soto National Forest, Mississippi. Poster delivered at 2006 Forest Health Monitoring Working Group Meeting, January 31-February 2, 2006, Charleston, SC, http://fhm.fs.fed.us/posters/posters06/katrina_tree_damage.pdf, accessed January 12, 2007.

